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Vision and Driving

Physiological basics and considerations with regard to spectacle lens solutions

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Abstract

Purpose. The number of accidents and road fatalities in Germany has been declining in recent years. This article aims at highlighting options that could potentially help to continue and strengthen this positive trend in the future.

Material and Methods. Various aspects regarding the requirements for obtaining a driver's license for passenger cars in Germany and the relevance of various parameters such as contrast sensitivity or glare sensitivity are examined. In this context, different basic physiological aspects of visual requirements are evaluated, along with study and analysis options and observations of the spectacle lens market. The literature review is based on studies and publications using relevant platforms such as PubMed.

Results. Especially at night, drivers experience subjective difficulties, for example with glare situations. This can be quantified using subjective surveys (questionnaires) on the one hand and measured in simulator, real driving or laboratory studies on the other hand. In addition to special materials or coatings, ophthalmic lens designs can also be adapted to the requirements of driving, which supports motorists in driving a vehicle safely. This primarily concerns cars drivers, however applications for other vehicles such as motorbikes, but also trucks or buses for passenger transportation are conceivable. In the future, in addition to spectacle lens-specific solutions, further considerations will need to be made on the subject of vision and driving: Adaptive (matrix) headlights are already reducing glare issues. Assistance systems can make a contribution to road safety. Finally, advances in automated driving could enable people with visual problems or even visually impaired people to participate in individual transport in the future.

Conclusion. In summary, it can be said that the field of mobility is currently undergoing major changes. With the right considerations, participation in road traffic can be made safer. Spectacle lens solutions can make a relevant contribution.

Keywords
Vision, Driving, Road Traffic, Roadworthiness, Spectacle Lenses

Introduction: Safety aspects regarding vision in road traffic

The Federal Statistical Office recorded 2,519,525 accidents in the Federal Republic of Germany for the year 2023, with a total of 366,557 injuries and 2,839 traffic fatalities.[1] With an overall stable and slightly increasing traffic performance of nearly 900 billion passenger kilometers in motorized individual transport [2], the number of accidents and traffic fatalities in Germany has decreased in recent years, as has the number of seriously injured individuals.[1] This is generally encouraging, but participation in road traffic still poses a risk. The risks of being involved in an accident appear to be particularly increased at night.[3]

This review article explores ways to maintain and enhance the positive trend of declining accident numbers in the future.

Methodology

To further strengthen the trend of declining accident numbers in Germany, safety aspects of driving play a crucial role. These are closely linked to the vision of vehicle drivers. In this regard, the following aspects have been researched:

After a brief introduction to the requirements for obtaining a driver's license for passenger cars in Germany, an evaluation of various physiological considerations regarding the requirements for vision and study as well as analysis possibilities is conducted. Spectacle lens solutions are also presented, along with a look into the future. This is based on studies and publications researched through relevant platforms such as PubMed. Additionally, observations specifically of the spectacle lens market were made.

Results

Requirements for driver's license issuing

Annex 6.1.1 of the German Driver's License Regulation (Fahrerlaubnisverordnung, FeV) stipulates that to obtain a driver's license (categories A, A1, A2, B, BE, AM, L, and T) in Germany, a visual acuity of 0.7 in both eyes must be demonstrated through an eye test. If this is not possible, an ophthalmological examination is required according to Annex 6.1.2. This examination must pay particular attention to visual acuity, visual field, mesopic and contrast vision, sensitivity to glare, diplopia, and other visual function disorders that could question safe driving. Minimum requirements are defined.[4]

The requirements regarding vision are currently not harmonized either within the European Union or with other countries. Although the European Union has Directive 2009/113/EC of the European Commission, which sets standards for driving, this directive only defines minimum criteria that EU member states should follow in their respective legislation. However, the actual criteria in the individual member states may be stricter. An overview is provided by the relevant work of Kobal and Hawlina.[5]

Kobal and Hawlina, in addition to comparing the requirements in various countries, examined the influence of different physiological parameters on driving safety, particularly in terms of accident risk (more on the topic of physiological considerations in detail in the following chapter). They summarize that, according to previous studies, visual acuity, which is most commonly tested, is only weakly correlated with a higher risk of traffic accidents, while the visual field plays a more significant role. Therefore, the inclusion of a visual field examination in the fitness to drive assessment appears important; however, a defined minimum requirement remains unclear, and further research seems necessary.[5]

The German Ophthalmological Society (Deutsche Ophthalmologische Gesellschaft, DOG) and the Professional Association of Ophthalmologists (Berufsverband der Augenärzte, BVA) issue recommendations for assessing fitness to drive for road traffic. According to these recommendations, a normal visual field of one eye or an equivalent binocular visual field is required for a Class B driver's license (passenger car). Particularly, the majority of traffic events relevant to the driver occur in the central area within 25° to 30° eccentricity. Binocular overlapping visual field defects in this portion of the visual field mean absolute unability to drive, even if the defects are extremely small in extent.[6]

Impairment of color vision was not recognized as a risk to traffic safety. Contrast sensitivity decreases with age and is affected by certain eye diseases. Glare, which may result from media opacity increasing with age, can particularly lead to a higher risk of traffic accidents at night for older individuals and those with conditions that increase glare or impair contrast sensitivity.[5]

More detailed information on obtaining a driver's license and the corresponding vision requirements can be found in the article "Requirements for Vision for Obtaining a Passenger Car Driver's License in Europe and the USA / Anforderungen an das Sehvermögen für den Erwerb des PKW Führerschein in Europa und den USA", published in this issue of the journal Optometry & Contact Lenses.[7].

Physiological parameters and their influence on fitness to drive

Visual acuity

In the German-speaking region, the parameter commonly used to determine fitness to drive is visual acuity. According to Annex 6.1.2 of the driver's license regulation (FeV), the minimum requirement is a visual acuity of 0.50 in the better eye or in both eyes.[4] However, the assessment is typically conducted using a screening test. Only if the minimum requirements of the screening test (visual acuity of 0.70 in both eyes) are not met, an ophthalmological examination becomes necessary, during which other parameters are also considered (see Chapter 3.1 Requirements for driver's license issuing).[4]

Visual acuity characterizes spatial resolution and is measured under photopic conditions (i.e., in bright light). Suffi-

Figure 1: Difference between visual acuity and contrast reduction: ***A*** *original image;* ***B*** *visual acuity reduction to VA 0.6, simulated by using a corresponding Bangerter film;* ***C*** *contrast reduction by 50 %, induced by post-processing the image with a neutral gray filter.*

ciently high visual acuity is necessary to recognize driving conditions such as boundaries, oncoming vehicles, signals, and road signs from a certain distance.

Contrast sensitivity

Wood and Owens (2005) investigated whether clinical visual acuity or contrast sensitivity measured under various luminance conditions can predict drivers' recognition performance under real-world on-road conditions during day- and nighttime. They found that recognition performance under real-world conditions was more accurately predicted by contrast sensitivity than by visual acuity measured under photopic conditions. Additionally, contrast sensitivity strongly correlated with visual acuity measured under low-light conditions (6.5 and 0.65 cd/m^2).

Given that the risk of accidents is particularly increased at night, this raises the question of whether considering contrast sensitivity in the standard assessment of fitness to drive would be beneficial. However, this question remains open at the current time.[8] (**Figure 1**)

It is important to consider the distinction between photopic and mesopic contrast vision. According to Hertenstein et al. (2016), if photopic contrast vision is poor, mesopic contrast vision is also poor. However, if photopic contrast vision is good, mesopic contrast vision can still be pathologically impaired.

For this reason, the measurement of photopic contrast vision has limited significance. In the context of assessing fitness to drive, mesopic contrast vision could be measured alternatively or additionally.[9]

Glare

A topic that is increasingly being discussed in connection with driving vehicles is glare.

In general, glare is understood as a visual condition that either appears uncomfortable or where the ability to recognize details or objects is impaired by an inappropriate distribution or a too high level of luminance or by extreme contrasts.[10]

There is a distinction between disability (physiological) and discomfort (psychological) glare, as the two forms are influenced by different factors (**Figure 2**).

Disability glare (also known as physiological glare) is understood as a form of glare that actually impairs the ability to recognize details (i.e., visual acuity or contrast sensitivity). It results from the scattering of light from all light sources in the field of vision through the optical media of the eye. The so-called veiling luminance created by this scattering (for an exemplary representation of the veiling luminance induced by vehicle headlights reduces the contrast of objects in the field of vision[13] see also **Figure 3**).

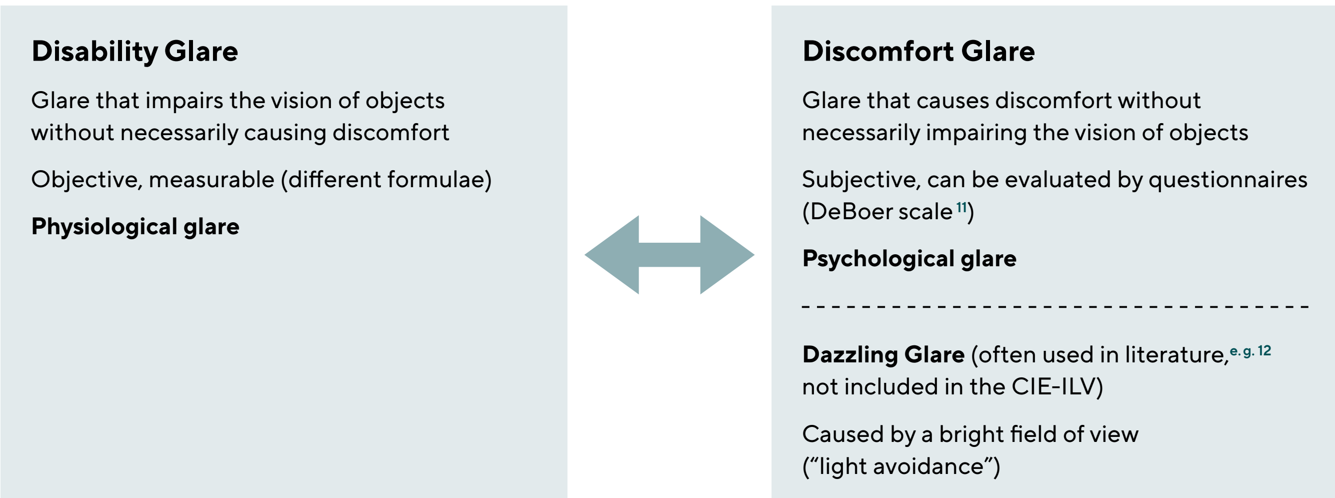

Figure 2: Glare definitions (according to[10,11,12]).

Figure 3: Exemplary representation of the veiling luminance induced by car headlights: The reduction of contrast due to stray-light becomes visible.

Disability glare is influenced by:

- veiling luminance
- glare angle
- age
- corneal scars, opacities of the lens and the cornea, etc.

Effects attributable to disability glare are not significantly influenced by the spectral distribution of the light source, its size, or the distribution of luminance itself.[14,15,16,17]

Discomfort glare (also known as psychological glare) can be described as a feeling of subjective disturbance or annoyance caused by bright light in the field of vision. Discomfort glare is usually measured using subjective rating scales such as the de Boer scale, which ranges from 1 to 9 (9 = just noticeable glare, 7 = satisfactory, 5 = just acceptable, 3 = disturbing, 1 = unbearable).[11,13]

It is influenced by:

- illuminance of the glare light source
- size of the glare light source
- glare angle
- spectral distribution of the glare light source, etc.

Discomfort glare can lead to distraction, subjectively perceived disturbance, light avoidance, and more.[13]

According to Vos 2003[18], there are several formulae that establish a relationship between physiological glare and age in healthy eyes. As previously described, physiological glare is the result of scattered light from light sources in the field of vision, caused by the refractive media in the eye.[13] Since opacities of the refractive media in the eye are widespread in older age, corresponding glare effects can accumulate and lead to increased influence.

Further parameters

Other parameters related to fitness to drive, particularly in the context of passenger transport, which are also mentioned in Annex 6.2 of the Driver's License Regulation (FeV), include visual field, color vision, mesopic vision, and stereopsis.[4]

The visual field essentially examines the Weber contrast in the near and far retinal periphery. More information about the visual field can be found earlier in the chapter "Requirements for driver's license issuing".

Regarding color vision, protanomaly and protanopia (red weakness and red blindness) are particularly significant, as they truncate the spectrum at the long-wavelength end. This suggests that there may be an impact on the recognition of rear or brake lights as well as signal lights. It is generally believed that an impairment in green vision does not affect road safety and does not lead to an increased accident rate, which is why there are no restrictions for this type of color vision deficiency.

Although a red color vision deficiency is not a disqualifying factor for obtaining a Class B driver's license (passenger car), it is relevant for passenger transport. According to the recommendations of the DOG and BVA, individuals with red color vision deficiency should be informed about potential dangerous situations in road traffic, particularly the risk of rear-end collisions.[6]

Mesopic vision is measured in the low-contrast range, also under glare, and can help assess night driving ability.

Stereopsis describes the ability to perceive depth, which ideally should fall within a range recognized as "normal". DOG and BVA provide a reference value for sufficient depth perception, stating that a stereo-angle threshold of 100″ is required.[6]

Study and analysis options

In the field of vision during driving, studies are conducted particularly regarding the subjective perception and objective impairment of vision due to glare, as well as comparing different correction solutions such as spectacle lenses, intraocular lenses after cataract surgery or assessing fitness to drive in certain conditions.

These studies differentiate between subjective methods such as questionnaires, which gather personal perceptions and experiences and objective studies conducted in laboratories, driving simulators, or during real on-road situations, which provide measurable data on visual performance and driving safety.

Subjective methods (questionnaires)

A relatively simple, intuitive, and popular method for the subjective assessment of vision during driving is the use of questionnaires. Some established questionnaires are presented below as examples.

The National Eye Institute Visual Function Questionnaire (NEI-VFQ) is a questionnaire that captures visual impairments of patients with various eye diseases regarding activities of daily living. It includes driving as a significant activity but is not limited to it. The questionnaire is available in different languages, including a validated German version, in addition to the original English version. This tool is valuable for assessing how visual impairments affect various aspects of daily living, including driving, thereby providing insights into the impact of eye conditions on individuals' quality of life.[19,20,21]

Additionally, the previously mentioned de Boer scale can be used to subjectively assess discomfort glare.[11]

In addition to these validated and research-established questionnaires and assessment methods, various studies commonly use custom-designed questionnaires tailored to the specific study design, sometimes employing visual analogue scales (VAS) and sometimes using Likert scales.

Simulator, on-road and laboratory studies

In addition to the subjective assessment of visual impairment, there are various objective methods. In laboratory studies, halos and other disturbances, such as those occurring after the implantation of multifocal intraocular lenses, can be subjectively and objectively simulated and measured. Kohnen and Suryakumar (2021) provide an overview of these methods.[22]

An examination such as halometry, which involves the measurement or subjective assessment of individual halo sizes, can in principle also be used with the aid of a driving environment in a simulator (for the measurement of parameters, see for example [23,24]).

Driving simulators now also allow for the measurement of vision-related parameters such as visual acuity or contrast sensitivity while driving.[3] This includes evaluation during nighttime driving, even under real glare conditions.[3,25,26]

Additionally, eye-tracking studies allow for the investigation of visual and driving behavior. These studies can examine the influence of the arrangement of displays and input devices in the vehicle. For instance, it has been shown that the arrangement of displays in the car and the use of head-up displays have positive effects on the efficient transfer of information to the driver.[27,28] It can also be assumed that the driver's visual and gaze behavior adapts to the arrangement and availability of such systems.[29,30,31]

Such studies can, in principle, be conducted both during real on-road driving and in a simulator.

The question arises as to what purpose driving simulators serve compared to real on-road driving; more specifically, why is the significant effort of setting up a driving simulator worthwhile in order to create a situation that is as close to the real world as possible?

The main reason for this can be found in the high complexity, or rather the lack of standardization, of real-world driving scenarios. It seems almost impossible to create comparable conditions regarding road surface, weather (such as precipitation or wind), lighting conditions, etc., for multiple real driving sessions – especially since these must often be conducted by participants on different days. For the routes used, if they were to be standardized as much as possible, even a closure for normal traffic would need to be considered.

For insurance reasons, in some cases of real on-road driving, such as when participants with certain eye conditions or unclear fitness to drive are to drive, a second set of pedals (dual-brake) must be installed in the vehicle, which can only be operated by a trained driving instructor. In contrast, a driving simulator allows for such experiments to be conducted in a highly standardized environment without jeopardizing the safety of participants or others.[3]

On the other hand, it seems questionable whether direct conclusions can be drawn from simulator studies to real on-road driving situations. There are individual studies where such comparisons have been made in the past.[32,33] Precisely speaking, every setup (route selection, lighting conditions, exact measurement procedure, etc.) in a driving simulator would need to be validated through on-road driving. However, it is not expected that such a significant effort would be routinely considered for simulator studies. Nonetheless, possibilities for this have been demonstrated in the past.[3]

Spectacle lens solutions

Materials and coatings

As described above, both the ability to participate in road traffic and visual comfort can be influenced by contrast vision and glare. Glare is a well-known phenomenon that has been exacerbated by the development of headlights from incandescent bulbs to halogen, xenon, and now LED headlights.[34]

A survey conducted among motorists in 2014 shows that they are willing to spend a certain amount for better vision in road traffic. Approximately 60 % of respondents indicated that they are willing to pay an additional 300 euros or more for improved vision in nighttime road traffic.[35]

Even though this study is now over 10 years old, it can be assumed that sufficient vision while driving at night is still considered relevant today.

Spectacle lens manufacturers have been addressing these challenges. Special materials and/or coatings for so-called drive lenses were presented. There are essentially two different approaches to this: The first one is to maximize contrast, which is typically achieved through anti-reflective coatings helping enhance contrast and reduce reflections that can interfere with vision.[34] Another approach is to reduce glare, particularly in the blue part of the light spectrum, either through special coatings or by modulating the transmission properties of the eyeglass lens material. In the mentioned blue part of the light spectrum, LED headlights have a spectral peak. Additionally, psychological glare, as previously explained, is influenced by the wavelength or spectrum of the light. Shorter wavelengths, such as bluish light, are subjectively perceived as more disturbing. By targeting this part of the spectrum, spectacle lenses can help alleviate the discomfort caused by glare, enhancing visual comfort.[36] The reasons for this are not fully understood, but potential factors include the stronger scattering of blue light within the ocular media (greater scattering effect at shorter wavelengths [36]) and longitudinal chromatic aberration.[37] Spectacle lens materials or coatings that reduce the blue component of glare can therefore be perceived as subjectively more comfortable.

Lens design and vision zones

Spectacle lens designs can be optimized for driving tasks. To achieve this, the optical aberrations that are unavoidable in the manufacturing of lenses are preferably shifted to areas of the lens that are less used for driving.

A large, clear distance vision zone is important for driving, as it allows for a good assessment of road traffic. The intermediate vision zone, where displays such as speedometers,

Table 1: Overview of selected lenses specifically for driving (according to manufacturer information available online, as of August 12, 2025; product names may be subject to trademark protection by individual manufacturers). Labels: D: design, T: treatment (summarizing material and coating properties).

Manufacturer	Lens	Source/s
EssilorLuxottica	Crizal Drive (T)	https://ecp.essilor-pro.com/gb/essilor-lenses/lens-coatings/crizal-drive
Hoya	EnRoute / EnRoute Pro (D, T)	https://www.hoyavision.com/vision-products/special-lenses/enroute/
Rodenstock	Solitaire Protect Road 2 (T)	https://www.rodenstock.de/journal/autofahrer-beim-brillenkauf
Rupp & Hubrach	EyeDrive mit Surround View (D) und Reflect Control Technology (T)	https://www.rh-brillenglas.de/de/sehen-neu-erleben/sehwelten/sehen-und-fahren
Seiko	Seiko Drive (D) mit SRC-Road (T)	https://www.seikovision.com/de/brillenglaeser/drive/
Shamir	Driver Intelligence (D, T)	https://shamir.com/for-professionals/shamir-driver-intelligence/
Zeiss	DriveSafe (D, T)	https://www.zeiss.de/vision-care/fuer-augenoptiker/brillenglaeser/brillenglaeser-fuer-jeden-bedarf/brillenglaeser-fuers-autofahren-und-mehr.html

infotainment systems, and navigation are located, should also be clearly visible, and a clear view into the side mirrors should not require unnatural head movements. The near vision zone appears to be less critical when driving.

In specialized drive designs, an ergonomically reasonable vehicle interior and dashboard layout is typically used as a basis, upon which the lenses are then optimized regarding their optical aberrations. Currently, lenses for driving cars are widespread in the market.

Table 1 provides an overview of selected lenses according to manufacturer specifications, which does not claim to be exhaustive. In summary, the following properties are indicated:

- special lens design for wide vision zones in intermediate distances (dashboard, mirrors): e. g. Hoya EnRoute and EnRoutePro, Rupp & Hubrach EyeDrive (Surround View), Seiko Drive, Zeiss DriveSafe
- special lens design for dynamic switching between near or intermediate and far distances: e. g. Seiko Drive
- material and/or coating for glare reduction: e. g. Essilor Crizal Drive, Hoya EnRoute and EnRoute Pro, Rodenstock Solitaire Protect Road 2, Rupp & Hubrach EyeDrive (Reflect Control Technology), Seiko Drive SRC-Road, Zeiss DriveSafe
- material and/or coating for contrast enhancement: e. g. Hoya EnRoute Pro, Rodenstock Solitaire Protect Road 2, Shamir Driver Intelligence

According to the manufacturers' websites, efficacy evidence is typically provided in the form of internal wearer trials (e. g. glare reduction for Essilor Crizal Drive or customer satisfaction for Zeiss DriveSafe), as indicated in Table 1. Occasionally, results from laboratory tests are also presented (e. g. glare reduction for Zeiss Drive Safe, study in collaboration with Hella GmbH & Co. KGaA, Lippstadt, Germany).

For lenses specifically designed for driving with long-pass filters (Hoya Drive Standard and Professional), positive effects on visual acuity under mesopic conditions, visual acuity under glare, and contrast sensitivity have been demonstrated.[36]

Lenses for operating other motor vehicles, such as motorcycles, trucks, or buses for passenger transport, could also be considered, as they require different visual behavior. For example, when driving a truck or bus, the fields of vision differ from those in a car and require a different arrangement of mirrors, particularly for rear visibility through mirror systems.[38]

Additionally, there is currently a trend in the truck sector moving from traditional mirrors to mirror replacement systems that operate using cameras and displays. Here, both the altered position of the displays compared to the previous mirrors and the changed accommodation requirements for focusing on the display instead of looking into the distance through the mirrors could be taken into account.

Conclusion and outlook: Road traffic in the future

In summary, it can be stated that the issues of glare in road traffic and the visual zone requirements are particularly addressed by spectacle lens manufacturers. Established principles such as vision zones and eccentricities to see instruments clearly are taken into account in the development and testing of specialized driving lenses.

In the future, further current developments in the automotive sector could help make driving safer and more comfortable. These include, in addition to smart lighting concepts such as matrix headlights, driver assistance systems and the next steps towards automotive driving.

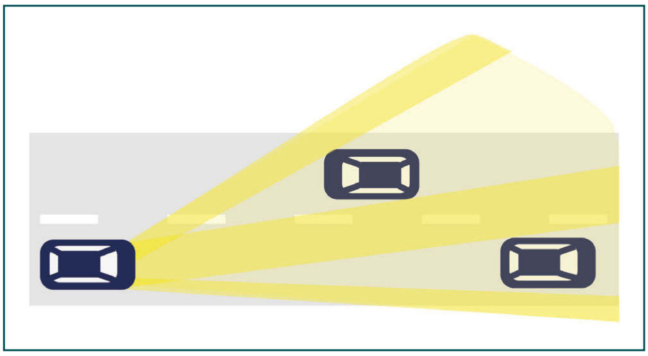

Figure 4: Schematic representation of the function of a matrix headlight: Glare for oncoming vehicle drivers is reduced.

Smart lighting concepts

Automobile manufacturers also recognize the problem of glare in nighttime road traffic. An efficient method to counteract this is the use of adaptive headlights or matrix headlights, which dynamically adjust the lighting to reduce glare for oncoming vehicles and ensure optimal illumination for the driver. Figure 4 shows a schemativ illustration. Although it is assumed that such systems can improve driving safety[39], matrix headlights are currently criticized regarding their resolution and calibration methods to avoid errors. Additionally, the question of the cost-benefit ratio arises concerning scalability issues across different vehicle categories.[40]

Another available technology is adaptive bending headlights, which dynamically move in the direction of a curve's bend. By providing better illumination of the road, it is intended to contribute to safety during night driving.

Assisted driving

The automation of driving is described in 5 levels by SAE (Society of Automotive Engineers International), BASt (Bundesanstalt für Straßenwesen, Federal Highway Research Institute), and VDA (Verband der Automobilindustrie e.V., German Association of the Automotive Industry):

0 no driving automation
1 driver assistence
2 partial driving automation
3 conditional driving automation
4 high driving automation
5 full driving automation

More information can be found in SAE J3016.[41]

Driver assistance systems such as lane-keeping assistants and parking assistants fall under levels 1 and 2. They are widely used today and can support driving safety; however, they do not necessarily address the issue of visual disturbances while driving. Further steps towards driving automation are necessary to tackle this problem.

For higher levels of automated driving, particularly when camera-based systems can independently initiate braking processes or indicate the necessity of such actions, driver support in recognizing obstacles and dangerous situations becomes possible. This can assist in compensating for visual deficits such as visual field losses, as well as increased glare sensitivity (especially in cases of physiological glare).

However, it should be noted that camera systems can currently be affected by glare sources such as the setting sun or by dirt, which can lead to misinterpretation of the environment.

Full driving automation – automotive driving

The progress towards full driving automation varies across different countries: While in San Francisco, USA, a self-driving taxi fleet by the manufacturer Waymo is already in operation, Germany, as described above, is proceeding more cautiously. In the latter case, the focus is particularly on prioritizing the safety of road users.

As described above, misinterpretation of camera signals can lead to incorrect assessments of the environment and necessary reactions. In the worst case, automated driving itself can become the cause of an accident. This raises the question, alongside existing technological shortcomings, of how to ethically address the misinterpretation of data in automated driving. This issue is currently unresolved. If a technologically feasible solution that appears ethically acceptable could be found, the concept of potentially full driving automation offered numerous advantages: In addition to increased road safety, accompanied by a thoughtful implementation of a higher degree of automation[e.g. 42], fully automated vehicles can enable elder individuals or people with physical impairments especially of the visual system, to participate in individual transportation and thus remain mobile. This is particularly essential for social participation in rural areas.

Conflicts of interest

Judith Ungewiss and Christian Lappe are both paid employees of Carl Zeiss Vision International GmbH. Judith Ungewiss received a doctoral fellowship with funding from the Ministry of Science, Research, and the Arts of Baden-Württemberg as part of the HAW-Prom program. She is a co-inventor on several patents/patent applications in the field of psychophysics. Christian Lappe is a co-inventor on several patents/patent applications in the field of spectacle lens manufacturing.

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